More recently (Kul'vanovskiy et al. [9]), there is evidence that still further refinement of the techniques for studying the bioelectrical activity of neural specimens is taking place (see Fig. 3). This F-shaped wet chamber consists of a thin, glass housing the size of which can be adjusted to conform to individual experimental conditions and problems. The main feature of such a

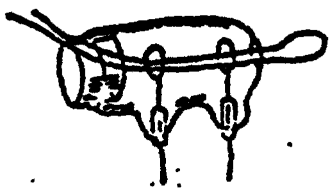

Fig. 3. Wet chamber for studying the bioelectrical activity of neural specimens

chamber is the freedom of recording nerve biopotentials under virtually normal, *in vivo* conditions. In their experiments, the authors used wet chambers with the following dimensions: 5-mm glass tubing 15 mm long with 2-mm projections for the insertion of platinum electrodes. The electrodes are tightly fixed in the orifices of the F-projections and are looped at the ends. The loops are 2 mm in diameter and the distance between electrodes is 5 mm. These simply constructed chambers guarantee constant electrical contact with the nerve and may be placed among the organs and tissues containing neural specimens. Since damage to the specimen can be avoided through the use of wet chambers, and since temperature and humidity integrity are assured by the surrounding organs or tissues, the prolonged viability of neural structures is possible. While the application of such a system in microwave research is not mentioned, it seems likely that the principle could find application here if the appropriate housing materials were used.

As earlier stated, relatively few definitive *in vivo* and especially *in vitro* investigations on the neural effects of EMF's have been reported by the Soviets. Kholodov [10] studied the effects of UHF (1000 v/m) on neuronally isolated sections of the cerebrum and midbrain of rabbits. Exposure duration was 2—3 min with 20—40-min intervals between exposures. Kholodov compared his results with the bioelectrical activity of intact brains and found that the latent period of the reaction of a neuronally isolated cortical specimen to UHF was 27 sec, as opposed to 53 sec for an intact brain. The UHF aftereffect duration for the former was shorter (1—5 min) than for the latter (15—20 min). Kholodov did not speculate whether these effects were of a thermal or nonthermal nature and this could not be ascertained from the irradiation parameters described. However, the results of this study are consistent with other, parallel investigations which have shown neural excitation to be characteristic of the response to microwave-range EMF's.

Perhaps the best controlled and most definitive research on the effects of microwaves on specific neural functions is reflected in a report by Yu. I. Kamenskiy [11], who studied the functional state of the frog nerve *n. ischiadicus*, during exposure to pulsed and continuous 10—12.5-cm waves (1—11 mw/cm^2). In this study, he first determined the thermal parameters of the microwave regimens used and selected an intensity of 11 mw/cm^2, which was sufficient to increase the temperature of the neural specimen by 1°C after an exposure of 20—30 min. The effects of continuous microwaves (12.5 cm, 11 mw/cm^2, exposure duration 20 min) were studied in the first series. In 34 tests, no reliable changes in threshold sensitivity were noted. The author did note, however, increased conduction rate, abbreviated absolute and relative refractory phases, and altered action current amplitude, which he judged to be of a thermal nature.

Most interesting were his tests with pulsed microwaves (10 cm, 1 msec pulse, 700 pulses/sec, exposure duration 20—30 min). Here, a definite increase in neural conduction and excitability was observed and was judged to be a result of the nonthermal (specific) effect. His reason for this conclusion was that at a frequency of 700 pulses/sec (pulse interval 1.4 msec) there was a summation of neural shifts. The pulsed intensity of radiation here was 1400 times greater than the mean level of intensity during continuous irradiation. Also, at frequencies of 100 and 200 pulses/sec, the pulse interval (5—10 msec) was too great to result in summation. Finally, the 0.2°C increase observed in specimen temperature during pulsed irradiation could not explain the five- to tenfold increment in conduction rate over values obtained when specimens were physically heated. Thus, definite, recordable shifts in neural excitation were observed during pulsed 10-cm-wave irradiation which could not be observed during continuous irradiation. The results of this investigation support the widely held Soviet view that pulsed microwaves are more biologically active in the neural sense than continuous (nonpulsed) microwaves.

Curiously, there is no evidence that Kamenskiy has continued research along these lines since 1964. However, another approach which has recently received more attention is being pursued by Presman [12], with whom Kamenskiy has collaborated in the past [8].

In [12] Presman studied the effects of pulsed and continuous 0—12.5-cm waves on the so-called excitable system of paramecia as possible approach to revealing the nonthermal mechanisms of microave effects on higher neural structures. He had previously demontrated that paramecia, when exposed to a-c and d-c currents, exibited an "electric shock reaction" (ESR) at certain threshold doses. n this study, he exposed paramecia located in a polystyrene chamber illed with a hay infusion and attached to the microwave generator to ontinuous, 12.5-cm waves in doses of one per second (dose duration —100 msec). This parameter resulted in a reaction similar to the SR. A second series was exposed to pulsed (200—700 pulses/sec) 0-cm waves with 7—50 msec durations once per second. This paraeter revealed that the mean power threshold values for pulsed microaves were higher than for continuous microwave values. As in amenskiy's study with the frog nerve [11], a cumulative effect was haracteristic of the pulsed 10-cm waves. It is interesting to note hat Presman used the same parameters Kamenskiy used in his experients. Since both these researchers collaborated in the design of quipment for these neurally oriented studies, it is entirely possible hat they both used the same hardware.

Presman's third and fourth series of investigation were designed o ascertain whether microwaves sensitized paramecia to electrical curents. It was found that microwaves decreased the threshold voltage ecessary to evoke an ESR. The author interpreted these results, toether with the fact that heating did not exceed 1.5°C in any series, o indicate the nonthermal effect of microwaves. His arguments against thermal explanation of the mechanism of the observed microwave effects ere as follows: 1) excitation threshold values for pulsed and coninuous microwaves were a function of the quadratic root of their dose uration or series; and 2) virtually no relationship between pulsed hreshold power and frequency was noted. Presman was satisfied that his approach and the data obtained in this study would help to clarify he mechanism of microwave effects on the "excitable" (neural) strucures of higher animals.

Presman's results have closely paralleled Kamenskiy's, despite he difference in the specimens studied. Since Presman and Kamenskiy ere (or still are) collaborators, the same approaches to the problems f neural reactions to microwaves have been employed. All of the tudies treated in this section, including Presman's and Kamenskiy's, trongly favor the theory that the mechanism of microwave effects on eural or neural-like structures is nonthermal, based on experiments n which threshold or nonthermal field intensities were investigated. inally, while one might expect that the interesting results of the studies entioned here would lead to an increased research effort in this area, there has been no recent perceptible increase in the number of articles devoted to this problem.

4. In vivo neural effects

A large complement of the Soviet research community devoted to the neural effects of microwave-range EMF's has used a more indirect approach to the problem. Here, the function or behavior of the whole organism or parts of it are studied during the action of various EMF irradiation parameters (local or whole-body irradiation). External, or functional patterns are deduced to reflect internal neural effects in the absence of any investigation of the neural structure itself. As regards the problem of classifying microwave neural effects as thermal or nonthermal, the results of many investigations are doubtful in this respect inasmuch as the biophysical, chemical, and even thermal parameters of alleged nonthermal effects have not been investigated. Another drawback of this indirect approach is the difficulty (if not absolute impossibility) of determining just how much microwave energy has reached the neural structures in question. This problem of comparative, *in vivo/in vitro* tissue dosimetry is of open concern to many Soviet researchers, Presman [5,6,13] in particular. The general consensus is that comprehensive research on this problem is absolutely necessary if the specific mechanisms of EMF effects are to be revealed. Nonetheless, the majority of Soviet researchers in this field feel that the behavioral and functional approach to studying EMF effects is a valid one in that it is possible to observe trends in biological responses to EMF's which clearly differ from responses to other, better understood stimuli. Therefore, this section will review some of the more recent works supporting this belief.

As far back as 1960, Presman [13] concluded that "Experimental studies in the Soviet Union and abroad have clearly indicated that, along with a thermal effect on the living organism, microwaves also have a so-called 'specific' effect" (a term that Presman coined himself). Functional shifts have been observed in the nervous and cardiovascular systems, as well as hematological and metabolic changes resulting from chronic exposure to 10—12-cm UHF at nonthermal intensities of 5—10 mw/cm^2. He was cautious enough to point out that, "The effective (medical) application of a specific effect of microwaves is possible only if the mechanisms of such an effect have been fully established."

It should be mentioned here that many different microwave research-oriented groups are active in this approach to revealing the behavioral and functional mechanisms of EMF effects. In fact, it is safe to say that hygienists (both military and civilian), hysiologists, biologists, and theoreticians have at one time ngaged in, or still are pursuing microwave research on animals nd their various systems.

Gorodetskaya [14], representing the active Ukrainian roup at the Bogomolets Institute of Physiology, studied the ffects of SHF (3 cm, pulse frequency 577 cps, power density .4 w/cm^2) on the behavior of mice (and their progeny) situated 0 cm from the generator. To "eliminate" thermal effects, conrol animals were convection-heated in an incubator for 15 min ntil a temperature of 52°C had been attained. This temperature ncrease paralleled microwave-induced temperature increase. orodetskaya found that SHF had a more pronounced effect than eat on the genital organs, and therefore on the progeny of irradiated animals, and that female animals were more sensitive o SHF in this respect. Changes induced by convectional heat in ematopoietic organs were less severe than SHF-induced changes. f interest relative to the neural effects of the wave range was he fact that the experimental animals exhibited more pronounced onditioned-reflex reactions in the form of negative responses han the controls. These reactions were found to be most proounced immediately after the termination of irradiation. While convection-heated animals began to recover one day after exposure, SHF-irradiated animals did not begin to recover until the third or fourth day after exposure; recovery was virtually complete for control animals on the second day, while for SHF-irradiated animals, it took five days. Gorodetskaya therefore concluded that SHF has more pronounced effect than convection heat. The results of this study support the "specific" affect theory of Presman [5,6,13], and also support the widespread Soviet opinion that pulsed microwaves are very active biologically. Notwithstanding the fact that this was a "hot" (0.4 w/cm^2) experiment, neural and other responses were observed that could not be explained by a purely thermal effect. It is therefore possible that the nonthermal or specific effects of microwave EMF's can be observed even under highly thermal microwave conditions.

Another representative of this group, Faytel'berg-Blank [15] investigated the effects of 12.6-cm UHF (70 v for 10 min) on gastrointestinal glucose absorption processes of isolated preparations from dogs and rabbits. Unfortunately he did not describe the radiation parameters of the experiment in much detail. For instance, it could not be ascertained how far the preparations were located from the Luch-58 generator, what the power density of the field around the preparations was, whether pulsed or nonpulsed microwaves were used, what the thermal parameters of the specimens studied were, and therefore, whether the effects observed were of a thermal or nonthermal nature.

Innervated, partially denervated, and completely denervated specimens were investigated and the results were processed using a method of variation statistics. Faytel'berg-Blank found that a ten-minute exposure of the epigastral region to a 70-v, 12.6-cm wave field did not alter intestinal glucose absorption in a dog whose solar plexus had been eliminated. He concluded that sympathetic nerves, the solar plexus in particular, participate in the transmission of a microwave effect from the epigastral region to the intestinal region. The vagosympathetic system also plays a substantial role in this respect. When vagosympathetic nerves are blocked at neck level, the stimulating effect of UHF on resorption is impeded. When spinal ganglia are blocked, UHF slightly elevates the level of resorption but to a lesser degree than when the ganglia are intact. The role of skin receptors was also demonstrated. Thus, not only peripheral neural elements of the GI tract, but also central nervous mechanisms were observed to be responsible for transmitting UHF effects. However, since some shifts in resorption were observed even in denervated specimens, Faytel'berg-Blank proposed that humoral factors are also affected by UHF. In an attempt to further reveal UHF mechanisms, he studied cell respiration in the specimens and found that UHF caused a shift in this function also. He speculated that this might be a reflex response (UHF acting or controlling neural elements) or evidence of a direct UHF effect on the cells.

The results of Faytel'berg-Blank's study are difficult to interpret. However, the stimulatory effect of UHF on neural structures again was observed. This agrees with the results of most other investigations so oriented.

Another resorption study was conducted by Yatsenko [16], who investigated the effects of a 20-min exposure to 12.6-cm waves (40 v, no values for power flux density or the distance of the preparation from the 5—6-cm electrodes of the "Luch" generator given) on the absorption of radioactive phosphorus by knee-joint synovial membranes. This function was studied in normal animals and those with severed spinal cords. Absorption activity was found to increase during the action of UHF. Spinal cord elimination alone retarded absorption, while under the effects of UHF, synovial absorption increased. Yatsenko felt that this was evidence of a direct UHF effect on synovial receptors and cited Faytel'berg-Blank [15] relative to the effects of UHF on peripheral nerves. Again, since no thermal parameters were mentioned in this study, it is unsafe to speculate that this study demonstrated the specific effect of UHF on central or peripheral neural function.

Semenov [17] better described the radiation parameters in an investigation of the thermodynamics of innervated and denervated femoral tissues in rabbits exposed to 12.6-cm waves (150—300 mw/cm^2, presumably a nonpulsed field, 10-min exposure duration, 3-, 4-, and 24-hr intervals between exposures). This was clearly a hot experiment and the author described in detail typical temperature-increase values for femoral tissue during irradiation. Semenov attributed a thermal cumulation or summation effect to neuroreflectory processes in the central nervous system. To test this hypothesis, he anesthetized animals and increased power density from 150 to 300 mw/cm^2 and found that the cumulative thermal effect was almost entirely precluded. He was therefore satisfied that sufficiently intense UHF fields are powerful stimulants which disrupt normal CNS adaptive processes, particularly tissue thermoregulation. Regrettably, he did not compare the effects of UHF with the effects of convection or local heating to add further strength to his conclusions. However, his study must be considered as further evidence that microwave EMF's affect CNS functions.

Using another approach to the problem of revealing microwave neural mechanisms, Pukhov [18] investigated the effects of neurotropic drugs (caffeine and medinal) on the viability of mice exposed to thermal (50 mw/cm^2), nonpulsed, 12.6-cm waves from a Luch-58 therapeutic generator. Exposure durations were 10 and 15 min, or the time necessary to kill the animals. Animals were irradiated 10 min, 60 min, and 24 hr following medinal injection and 60 min after caffeine injection. Pukhov found that caffeine, owing to its CNS stimulatory effect, statistically decreased the viability of irradiated animals, or, depending on the dose administered, resulted in no change. Medinal administered 24 hr prior to irradiation increased the viability of animals owing to its hypothermic effect. He could only conclude from this study that the mechanism of microwave effects on CNS functions requires further study. Here, the thermal (50 mw/cm^2) doses used would render difficult any concrete conclusion as to the specific effects of microwaves, especially nonpulsed waves, which Kamenskiy [11] and Presman [5,6] feel are basically thermal in their effect. However, this study would indicate that nonpulsed, thermal, 12.6-cm waves did have an excitatory effect on the CNS.

In an interesting article by Malakhov [19], the effects of weak, nonthermal doses of UHF on conditioned reflexes were considered from the standpoint that such fields might play an important role in actually triggering reflexes. Malakhov feels that this problem is germane to the hypothesis that UHF, or microwave range fields, might act as "information carriers" of extrasensory signals (see the conclusions and discussion of this report).

To test this hypothesis, he attempted to develop conditioned reflexes to a 13.7-cm UHF field (20 mw/cm^2) in mice by using 20-sec conditioned (UHF) signals and 15-sec unconditioned signals. Responses were recorded oscillographically. The results of this experiment were disappointing in that reflexes to UHF, while demonstrable, were characterized by a long period of development, instability, a short residual effect, and rapid extinction. This same trend was observed by Kholodov [10], whose studies will be discussed in more detail in the next section. Malakhov could only conclude that weak UHF fields are of little "informative" (stimulatory) value to mammalian CNS patterns. He did state, however, that his results, while disappointing, deserved further investigation and that various animals (species not given) can serve as indicators (sensors) of microwave-range EMF's.

In a very recent article, Loshak [20] described an interesting experiment conducted to reveal the combined effects of pulsed UHF (1.0 mw/cm^2, other radiation parameters not given) and ionizing radiation (180-kv x-rays, 900-r whole-body dose) on white rats. Here, three groups of males were irradiated daily (2-hr exposure duration) 30 times. The first group was locally (head only) irradiated while the second group was whole-body-irradiated by UHF. The third group was used as a control and was irradiated by x-rays only.

The results of this study did not show preliminary microwave irradiation to have any protective effect, although Loshak, on the basis of other studies (not cited) had felt it might). He found, in fact, that pre-UHF exposure actually resulted in a more rapid mortality of x-ray-irradiated animals in both groups. The survival time for locally, pre-UHF irradiated animals was 17.1 $\pm$ 3.2 days, for whole-body-irradiated animals, 11.9 $\pm$ 1.0 days, and for control animals, 20.8 $\pm$ 2.1 days. Thus, decreased resistance to x-rays was the end product of nonthermal UHF exposure. Loshak attributed these results to the effects of UHF on hematopoietic structures, which in this study would imply that these organs are even more sensitive to decimeter-wave radiation than neural structures in view of the maximum mortality of whole-body-irradiated animals. Loshak stated that the lifespans of these animals indicated hematopoietic injury (especially of the bone marrow).

Unfortunately, Loshak's article appeared in abstract form, making it difficult for the reader to draw any concrete conclusions, especially those relative to the role of the CNS in this study. However, the fact that the group of locally (head only) irradiated animals also showed decreased resistance to x-rays is of interest. If, as Loshak stated, hematopoietic injury was responsible for decreased resistance to x-rays, an explanation is needed for the decreased (though not dramatically so, e.g., 17.1 ± 3.2 days vs. 20.8 ± 2.1 days) resistance of cerebrally irradiated animals. Above all, the fact that such a demonstrable biological effect was observed in response to such a low-intensity (1 mw/cm^2) decimeter-wave field is thought-provoking at the very least, since it would indicate a "specific" (nonthermal) biological effect of UHF. Loshak's observations also support the general Soviet opinion that pulsed microwaves are highly active in the biological sense.

5. Neural effects of low-frequency electromagnetic and magnetic fields

This section will briefly review some recent research on the neural effects of sub-microwave-range EMF's and constant magnetic fields. This area of research is of interest (with respect to magnetic fields in particular) because Kholodov [26,27], who is now active in magnetic field research, is also actively interested in research on the neural effects of microwave-range EMF's [10].

While research on low-frequency or very-low-frequency EMF's has been rather limited in scope and quantity, it is apparent from the research of Petrov [21] (1929), who initiated comprehensive research in this area, that Soviet interest in the biological effects of EMF's has had a long history. Petrov's last article in 1952 [22] demonstrated a weak and unstable reflex reaction to a low-frequency EMF. Since then, Sazonova's research [23,24] and Plekhanov's recent study [25] are the only indication of a continuation of Petrov's approach.

Sazonova [23] investigated the neural function of rabbits exposed to a 50-cps EMF generated by two 10-M transformers through 500-x 500-mm electrodes separated by 1200 mm. Each transformer generated a 65,000-v field. The *n. tibialis* nerve (*in vivo*) was studied using an ergographic setup which made it possible to load the paws of the animals with weights. Training prior to experimentation required one month. The field intensity ranged from 300—1000 v/cm. He found that these EMF parameters had a deleterious effect on motor function and that the effect of a 1000-v/cm field was more readily apparent than the effect of a 300—400-v/cm field.

In her second study [24], Sazonova continued to investigate the role played by the central nervous system in the motor activity of rabbits exposed to the same 50-cps EMF. Here, she used stimulatory and inhibitory neurotropic drugs (dibasol, novocain, aminazine) as a method of better revealing the neural mechanisms of the EMF effect. Animals were irradiated one hr daily, six days per week, for a month. In this study, a 100,000-v/m field was used. She found that inhibition of the reticular formation (tests with aminazine), or elimination of other neural pathways (novocain) delayed EMF-induced fatigue. Enhancement (dibasol) of CNS activity resulted in more rapid fatigue. Sazonova thus felt that she had demonstrated an EMF effect on the central nervous system relative to its participation in motor functions. It is interesting that the results of this study are similar to the results of some microwave experiments which indicate a stimulatory effect of EMF's on neural structures. Perhaps, as Osipov suggested in 1965 [32], a wide wave range of EMF's have a more or less analogous effect on the central nervous system.

More recently, Plekhanov [25] studied the effects of a low-frequency (735-kc) EMF on human conditioned reflexes to cold, using a plethysmographic technique which he felt was the best approach because of its sensitivity. A portable diathermy generator was used. He found that when field voltage was varied from 220—330 mv/m (110 mv/m variation), a conditioned reflex was noted which was attributable only to the variation in field voltage. He speculated that the mechanisms of the reception of this EMF range are to be found in the retina and skin receptors, the latter being specific EMF receptors. He concluded, however, that any living cells, especially neural cells of the brain, are EMF receptors, and that the mechanism of intracellular reception might be physical and chemical in nature. The possibility that EMF effects might be analogous to weak doses of ionizing radiation was not discounted. This would render the low-frequency EMF a nonspecific stimulus.

As to the effects of magnetic fields on "excitable" and neural structures, it is noteworthy that Yu. A. Kholodov [26,27], the leading Soviet spokesman for this research effort, has also been active in research on the neural effects of microwave-range EMF's [10]. In many respects, the approaches to investigating the neural mechanisms of magnetic field effects have paralleled the approaches to the microwave problem. Kogan et al. [28], like Pressman [7], studied the behavior of paramecia in capillary tubes exposed to magnetic fields of 160—180 oe. Twenty to thirty time measurements were made before, 60—80 during, and 20—30 after the action of the magnetic fields. It was found that paramecia preferred the south pole of a magnet, that magnetic effects were gradual, and that these effects persisted after removal of the field. The effect of a magnetic field was found to be a function of its strength. Kogan did not use Pressman's approach to this problem, in that he did not study the so-called electric shock reaction. He concluded that the magnetic effects he observed might be extracellular in nature (physical and chemical changes in the medium), and that this extracellular phenomenon might serve to explain the effects of magnetism on the functional state of organs and tissues. Kogan did not discount the possibility that magnetic fields might directly affect intracellular processes although he did not speculate on the possible mechanisms of such effects. Kogan did not cite Pressman's study [7] nor did he discuss the so-called excitable system of paramecia.

Kholodov [26] reviewed the results of some of his investigations on fish, frogs, and rabbits exposed to intermittent (50-cps) magnetic fields ranging in intensity from 1 to 1000 oe (average, 100—300 oe). He found that pigeons did not develop conditioned reflexes to magnetic fields, while fish did. He felt that reflexes were affected by magnetic fields via the diencephalon or diencephalic structures (he also mentioned these structures as EMF receptors in his microwave research [10]. EEG's showed magnetic reactions by rabbit brains 53% of the time in intact animals and 63% of the time in neuronally isolated samples. His approach here was analogous to his 1964 microwave study and, interestingly enough, the results were similar in showing a magnetic field to be a direct stimulus of the central nervous system. However, the effects of other factors in this study should not be discounted since, as Kholodov pointed out, variable (50 cps) magnetic fields were used.

In the same investigation, Kholodov studied the impulse activity of 23 isolated cortical neurons. He could not detect any change in their background activity during exposure to his magnetic field parameters, but did note that their sensitivity to light increased during, and one min after the action of the field. While Kholodov was cautious in pointing out that the number of neurons studied was insufficient to draw any concrete conclusions, he mentioned that a morphological analysis of glial cells showed them to be highly sensitive to magnetic fields (he did not specify whether he meant constant or variable fields). He suggested that the biophysical mechanisms of magnetic field effects on neural structures might well be elucidated by tracing the chemical activity of glial cells, the trophic function of which is generally accepted. Kholodov plans further research on this approach.

It will be interesting to see how (if at all) Kholodov's magnetic field research affects trends in future microwave research in view of his active interest in the latter.

Recently, Chizhenkova [29], as if in response to Kholodov's research, investigated the EEG activity of rabbits with chronically implanted electrodes (sensorimotor area of the right cerebral hemisphere) exposed to 300-oe constant magnetic fields. Activity before, during, and after the action of the field was monitored using six animals in 604 tests. He observed a definite stimulatory effect of the magnetic field and showed that it was not a function of switching the field on or off. He would not speculate on which CNS structure was a specific receptor of EMF's, and suggested that his future efforts would be devoted to comparing magnetic effects with those of weak doses of ionizing radiation. This might imply that Chizhenkova is unsure whether magnetic fields have a specific effect on neural structures.

In his most recent communique, Kholodov [27] discussed the biological effects of magnetic fields in terms of space biology and medicine. He proposed the use of magnetic, antiradiation fields for spacecraft and also stated that experiments have shown that fluctuations in magnetic field intensity shorten the lifespan of rats, increase the human flicker-fusion threshold, and affect the orientation of unicellular algae, higher plants, insects, mollusks, fish, and birds. Such fluctuations also affect the general health of people, as reflected in hospital statistics. Increased magnetic field intensity stimulates motor activity, decreases sensitivity to some stimuli, and affects EEG activity. Conditioned reflexes to a magnetic field can be developed in fish, but not in pigeons or rabbits (despite the alleged effects of magnetic fields on the former). Human visual images are altered during exposure to a magnetic field under the influence of hypnosis (see the discussion at the end of this report) and mescaline. Kholodov restated his belief that magnetic fields primarily affect glial cells, as reflected in individual neuron activity (perhaps he was referring to his 1965 research, although he did not cite any publications in this paper). He also stated that "magnetically treated water has a biological effect," although he did not discuss the mechanisms or pathways of this alleged phenomenon.

In general, it would appear from Kholodov's statements and research that the effects of low-frequency EMF's and magnetic fields (especially intermittent ones) have a direct effect on neural structures, and that these effects are similar to those produced by nonthermal microwave intensities. It will be extremely interesting to see whether Kholodov's view that the diencephalon and glial cells are specific EMF and MF receptors will be borne out by future Soviet research.

6. Clinical, therapeutic, and hygienic aspects

Soviet concern for the actual effect of microwave-range EMF's on humans has been no less intense than their theoretical interest in these fields. Moreover, this report will show that the last two years (especially 1966) have yielded a dramatic increase in the volume of material devoted to the therapeutic, clinical, and especially hygienic aspects of human exposure to microwaves and even magnetic and electric fields. Presently, the chief spokesman for hygiene is Yu. A. Osipov [32].

Otherwise, smaller and more isolated groups are sporadically active in this field. Atanelishvili [30], for example, compared the effects of various physiotherapeutic procedures on human motor response to light. The effects of UHF, diathermy, and pine baths were investigated. No UHF radiation parameters were described. A total of 71 patients with gastric disorders was examined, 41 of whom received UHF therapy. Atanelishvili found that UHF stimulated motor reactions in the majority of cases. However, he obtained basically the same results from diathermy and bath procedures, rendering any conclusions as to the specific effects of UHF on the central nervous system doubtful. He concluded that all three procedures altered the functional state of the CNS, which undoubtedly plays a prominant role in the positive effects of therapy.

As regards the hygienic aspects of human exposure to microwaves, it should be noted that this area of concern is of interest to both the military and civilian communities. The Soviet military medical service has played an active role in assessing hygienic conditions and the state of workers exposed to radar fields. Kapitanenko [31] conducted a clinical investigation on 100 young military personnel (66 exposed to radar, 34 control). UHF fields were generated by decimeter and centimeter generators. He did not provide any dosimetry data.

Kapitanenko concluded that the nervous system was the first system to react to UHF, and that the severity of neurological disorders was a function of field intensity and duration of exposure. Asthenia was a prominant neurological symptom of the deleterious effect of UHF. Cardiovascular disorders, also observed, were not sharply pronounced and were judged to be reversible. No specific therapy for UHF symptoms is known, although positive results have been obtained from: 1) intravenous injection of a 40% glucose, 5% ascorbic acid solution (dose and frequency of administration not given); 2) a strychnine and securinine solution (dose and administration details not given); 3) ginseng (no details given); and 4) 0.005 g of dibasol three times per day.

In his book reviewing hygienic problems of human exposure to microwave-range EMF's, Osipov (1965) [32] considered data from as far back as 1933 relative to the effects of microwave-range EMF's on the human nervous system and other systems. Among the many human CNS symptoms of microwaves consistently reported by Soviet observers are: loss of memory, migraine headaches, insomnia, dizziness, irritability, dermographism, and loss of appetite. Autonomic disorders have been characterized by changes in cardiac, hepatic, and gastro-intestinal function. As Osipov sees it, autonomic dystonia is a common symptom of exposure to microwaves. He concluded that the most common and persistent neural symptoms of microwaves are neurasthenia and autonomic (primarily vagotonic) dystonia. These symptoms are also observed as a result of exposure to the combined effects of microwaves and x-rays. Most microwave-induced shifts are reversible, e.g., pathological damage to neural structures is usually insignificant, according to Osipov. Rarely, microwaves can cause hallucinations, syncope, and adynamia (the diencephalic syndrome).

Osipov feels that the effects of EMF's are qualitatively identical within a wide spectrum (from long to ultrashort waves, 100 kc to 30,000 kc). His opinion is well borne out by the articles reviewed in this report, and although he does not discuss problems of exposure to purely magnetic and electric fields, it should be noted that Vyalov et al. [38] mention many symptoms characteristic of microwave effects (headaches, tremors, elevated pain sensitivity, dermographism) in workers exposed to constant magnetic fields (150—1500 oe). Asanova [39] reported characteristic microwave symptoms (dermographism, cardiovascular shifts, tremors, hyperhydrosis, headache, fatigue, asthenia, drowsiness) in workers exposed to electric fields (115—125 μ amp) in 400—500-kv hydroelectric stations.

Osipov also notes reports of reduced sexual potency and baldness induced by microwave-range EMF's. He feels that the latter might be attributed to the neurasthenic syndrome, although he states that a "psychological factor" should not be discounted.

It should be mentioned that Osipov, unlike Presman, Kholodov, Kamenskiy, and others, is inclined to regard the low-intensity effects of microwaves as "microthermal" effects rather than non-thermal effects.

Since Osipov's comprehensive review, there has been a virtual deluge of articles from the Institute of Industrial Hygiene and Occupational Diseases devoted to the hygienic aspects of meter-to-centimeter-range fields. Here the military effort should not be belittled. Smurova et al. [33] investigated medical personnel working around physiotherapy generators (1.6 to 2450 mc, λ equals 184 m to 12.2 cm). He found that working conditions around these sources exceeded permissible exposure limits, e.g., 20 v/m or 10 mw/cm^2, by as much as two orders of magnitude (170—1000 mw/cm^2). Here again, the characteristic EMF syndromes were noted (headache, irritability, insomnia, chest pain, dermographism, acrocyanosis, hand tremor, etc.). Impairment of light sensitivity and dark adaptation were judged to reflect increased CNS sensitivity. The characteristic cardiac symptoms were also noted. Smurova concluded that the wide wave range of fields studied were deleterious to human health, an observation which agrees with the findings of Osipov [32].

Drogichina et al. (1966) [34] concentrated on the autonomic and cardiovascular disorders of personnel exposed to microwave-range fields up to a "few mw/cm^2" in intensity. Along with the familiar asthenic syndrome, this group found that autonomic cardiac disorders were the most persistent characteristic of exposure to microwaves. They also attributed diencephalic disturbances (interesting in view of the theoretical material discussed in this report) and coronary spasms to microwaves.

Fukalova [35] sought to establish permissible limits for personnel exposed to shortwave (6—450 v/m) and ultrashort-wave (4—220 v/m) sources. She concluded that all observed CNS symptoms caused by these EMF's were aggravated by inefficient work-rest cycles. Fatigability was the most prominent of the familiar CNS symptoms observed.

To establish exposure norms, Fukalova exposed animals to 14-, 88-, and 69.7-mc fields (5000 v/m) and found that animals in the ultrashort-wave range were killed within 5 min, while 1 hr and 40 min was required for death in the shortwave field. She found the nonthermal threshold intensity (no increase in body temperature) for ultrashort waves was 150 v/m and for short waves, 2250 v/m. Chronic (duration not specified) exposure to these intensities caused a decrease in medulla oblongata cholinesterase activity more rapidly during exposure to ultrashort waves than during exposure to short waves. Brain biopotentials were depressed. An ultrashort-wave intensity of 10 v/m and a shortwave intensity of 50 v/m were found to be "threshold irritants." As in Lobanova's study [7], an ultrashort-wave intensity of 150 v/m was sufficient to cause thickening of neural fibers, protoplasmic swelling and vacuolization in the thalamo-hypothalamic area and medulla oblongata, and local karyocytolysis of individual neurons. Shriveling of occasional cortical pyramid cells and neuron vacuoles was also noted. On the basis of these data, permissible human exposure intensities (duration of exposure not given) were set at 5 v/m for ultrashort-wave fields and 20 v/m for shortwave fields.

The Soviet military medical service regards the neural and other effects of microwave-range EMF's no less seriously than the civilian community. Professor I. R. Petrov [36], a Major General in the medical service and member of the Academy of Medical Sciences USSR, concurs with the findings of the civilian community in that a microwave-field intensity greater than 10 mw/cm^2 constitutes a thermal hazard, and that microwave-range EMF's directly affect the human CNS.

Panov [37] in a recent article not only agrees that microwave-range EMF's directly affect human neural processes, but classifies these effects into three familiar symptoms: 1) the neurasthenic syndrome (reversible), ambulatory treatment indicated; 2) autonomic vagotonic dystonia (occasionally stable and irreversible), bed rest indicated; and 3) the diencephalic syndrome (visceral dysfunction, hypersomnia, hypokinesia, latent or overt hypothalamo-hypophoseal-adrenal depression, depressed sexual and food reflexes). Diencephalic changes are not always reversible and bed rest is indicated.

Thus, this section reflects the unanimity of the Soviet civilian and military communities, which feel that microwave-range EMF's (above 10 mw/cm^2) constitute an occupational hazard and that these fields affect the human central nervous system. Some of the clinical observations discussed in this section would tend to support the findings of such researchers as Presman, Kholodov, Kamenskiy, and others, who feel that microwaves exert a specific or nonthermal effect on neural structures.

Discussion

From the foregoing material, little doubt can remain that the majority of the extensive Soviet community concerned with the biological effects of EMF's (and MF's) are of the opinion that these fields, especially in the microwave range, directly affect neural structures and that neural structures (especially the CNS) are the most sensitive to microwave-range EMF's. CNS effects have been observed as a result of exposure to both nonthermal and thermal intensities of pulsed and nonpulsed microwaves. The research of the military and civilian communities has been largely parallel. There is some recent evidence that purely magnetic and electric fields can be included as microwave-like CNS stimuli.

At the present time, Soviet opinion holds that EMF's: 1) affect the structure and chemical reactivity of neural cells (Pressman [5,6,8], Kholodov [10,26,27], Kamenskiy [11], Tolgskaya [4], Livshits [1,2], and Lobanova [7] and others; 2) that they may also affect the molecular structure of neural structures by virtue of resonant or other absorption (Presman [5,6]; and 3) that the effects of EMF's are qualitatively analagous for a wide frequency range

(100—30,000 kc) and that nonthermal effects may, in fact, be of a "microthermal" nature in the absence of more concrete evidence to the contrary (Osipov [32] and Presman [6]).

The relationship between Osipov [32] and Presman [6] should be mentioned since there is a slight disagreement between the two relative to the nonthermal effects of microwaves. Osipov, while admitting there is evidence that microwaves have a biological, and especially a neural effect at field intensities which do not produce perceptible thermodynamic changes, feels that it is experimentally impossible to demonstrate a specific, e.g., nonthermal, microwave effect by comparing that alleged effect with a thermoequivalent control. He reasons that since biological objects are electrically heterogeneous and since microwave-range EMF's have a known selective thermal effect on various tissues and organs, a difference between a microwave effect and a neutral heat effect is not necessarily due to an unknown extrathermal factor, but might well be a function of an uneven distribution of heat in the organism which could exert its own peculiar effect. The specific action of a microwave EMF, in Osipov's view, should only be understood as a demonstrable transfer of EMF energy into nonthermal energy. He therefore feels that the many alleged "nonthermal" microwave effects accepted by Presman may well be "microthermal" effects in the absence of conclusive experimental evidence to the contrary.

Presman, on the other hand, is more inclined to believe that if a microwave EMF does not result in any perceptible temperature shifts in an organism, then any change in its behavior, function, or structure can be attributed to the nonthermal mechanism of the EMF, even if it is experimentally impossible to demonstrate that thermogenic and nonthermogenic EMF intensities each give rise to different reactions. In short, Presman feels that there is ample evidence of the nonthermal effects of microwave-range EMFs by virtue of an absolute temperature criterion while Osipov feels that, while nonthermal effects are entirely possible, they have not as yet been as well substantiated physiologically as thermal effects.

Far from abating, Soviet research efforts in this area show every indication of continuing at their present pace or even intensifying, as reflected in the recent large review articles, chiefly by Presman and Osipov. Presman's last comprehensive review, like Osipov's, was published in the last half of 1965. At the time of that writing, he estimated that approximately 1000 works had been published on the biological and medical aspects of microwave-range EMF's. That review, unlike his previous ones, concentrated heavily on the possible mechanisms of EMF biological effects. Most of the recent articles discussed in the 1965 review were cited by him as evidence of thermal, and, most interesting, nonthermal or specific effects of EMF's. Therefore, it would not be imprudent to expect that more attention will be paid to the biophysical mechanisms of nonthermal EMF neural effects than has been in the past, although at the present time, there is little evidence to support this expectation.

What the purpose is of such intense neurally oriented research in the realm of microwaves by Soviet theoreticians and practitioners is not entirely clear to this observer. While Osipov [32] states that thermal intensities are encountered much less frequently under industrial conditions owing to improved hygienic practice, clinical evaluations of the potential hazards of nonthermal intensities continue at a steady pace despite his theory that so-called nonthermal effects might well be "microthermal".

Presman [6] speculates that microwaves can be developed into a valuable tool for evaluating the physical, chemical, and, especially, molecular properties of tissues. The therapeutic uses of microwaves have been well established. Considering the rapid development of laser technology, it seems logical to expect that Soviet theoreticians, researchers, and hygienists will soon turn their attention to the biological, and perhaps even neural, effects of this factor. The Soviet use of lasers for ocular surgery is already well known (Helmholtz Institute of Eye Diseases). Recently, the first Soviet report to come to the attention of this observer on the biological effects of ruby laser radiation was published. Gorodetskiy et al. [42] described experiments designed to study the laser absorption characteristics of blood, skin, muscle tissue, and various other animal organs and tissues. No neural structures were mentioned, nor had any of the authors' names ever been noted in connection with microwave-oriented biological research. It seems reasonable to speculate, however, that the valuable experience gathered by microwave researchers would readily lend itself to laser problems.

Of incidental interest relative to the possible ramifications of microwave research is the recent announcement [40] that a special bioinformation section has been organized under the aegis of the Moscow Board of the Scientific-Technical Society of Radiotechnology imeni A. S. Popov. The purpose of this section is to study parapsychic phenomena; it is composed of radioengineers, technologists, hypnotists, medical doctors, biologists, and physiologists, including A. S. Presman, Yu. I. Kamenskiy, and Yu. A. Kholodov, the three leading Soviet spokesmen for the nonthermal effects of microwaves (and magnetic fields) on neural structures. This group held its first meeting on 11 October 1965 to discuss "Some Problems of Parapsychology." The section will proceed to analyze the world literature on parapsychic phenomena, to record and classify observable cases of "spontaneous" telepathy, and actually conduct experiments dealing with naturally reproducible telepathic phenomena. Professor and Doctor of Technical Sciences I. M. Kogan, Chairman of this Bioinformation Section, stated in the announcement that, "The era of sensation concerning telepathic phenomena is over. There is no need to dispute its existence, but rather a need to investigate its nature."

Since the initial announcement of the organization of this section in early 1966, only one additional bit of information has come to the attention of this observer concerning the actual function of that section [41]. This unsigned newspaper article published on 9 October 1966 mentions the familiar name of Yu. I. Kamenskiy as a participant in a telepathic experiment designed to differentiate the effects of a normal and hypnotic state on mental suggestion.

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bstract Accession No.:

This comprehensive report is based on Soviet open sources published 1952-1966 with a few sources published earlier. The primary purpose of the report is to outline Soviet research on the effect of low-intensity microwave radiation on the central nervous system of living organisms, including man. There are six sections in the report: (1) Scope of effort: organizations and individual researchers; (2) Subject development; (3) Specific neural functions and structures; (4) In vivo neural effects; (5) Neural effects of low-frequency electromagnetic and magnetic fields; (6) Clinical, therapeutic, and hygienic aspects. ~~Each of these sections may be read independently.~~ The Discussion which follows summarizes important facts and deductions from the foregoing sections and speculates on the intensity and type of Soviet research efforts in this area in the future. The bibliography at the end of the report includes 42 entries.

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